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An Automatic Data Acquisition and Reduction System

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A system for recording and automatically reducing up to 41 channels of slowly varying data has been designed. For recording, the data are multiplexed into a very slow speed, analog tape recorder. Playback can be done at speeds up to 1000 times as fast as the recording speed, using a 60 IPS tape playback unit. A digital clock provides time control and the data are digitized and punched onto paper tape at playback. The paper tape can then be used to input the data to conventional computer systems for various analysis and editing operations. The cost of the system is comparable to high reliability strip charts, for the same number of channels. Total system accuracy for input voltages in the ranges ±0.1 to ±10 v is ±0.3 percent.

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Many studies in meteorology and geophysics require recording slowly varying voltages over time periods on the order of months. Such records are commonly made with clock-driven strip-chart recorders, but the recovery of data from strip charts is a laborious process. We wanted to record the deformations of a snowpack for about 4 months, using 22 deformation sensors. We also wanted records of windspeed, wind direction, and air temperature. Because the job of recording this amount of information on strip charts and then recovering the data would have been overwhelming, we assembled a recording system which incorporates a very slow-speed, analog tape recorder, time-sharing data multiplexers, and a digital time code generator (fig. 1).

Data are recovered with a normal speed tape recorder, a time-code translator, a multiplexer, and a digital controller. The digital controller allows the data to be read by a digital voltmeter and then printed on a teletype and punched on a paper tape. The punched paper tape is read into a remote terminal linked to a
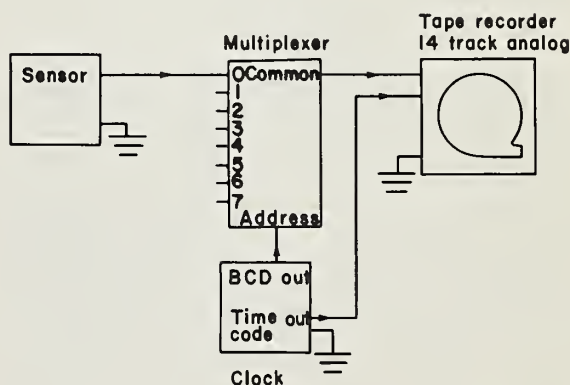
Figure 1.—Block diagram of the data acquisition system showing the flow of data from a single sensor, through a clock controlled multiplexer and onto one track of the tape recorder. Other sensors may be connected to other multiplexer channels or directly into the tape recorder. A time code which is synchronized with the multiplexer switching is recorded on one tape track.

time-sharing computer, edited with an available program, and dumped onto digital magnetic tape, (fig. 2), for computations with a local computer.
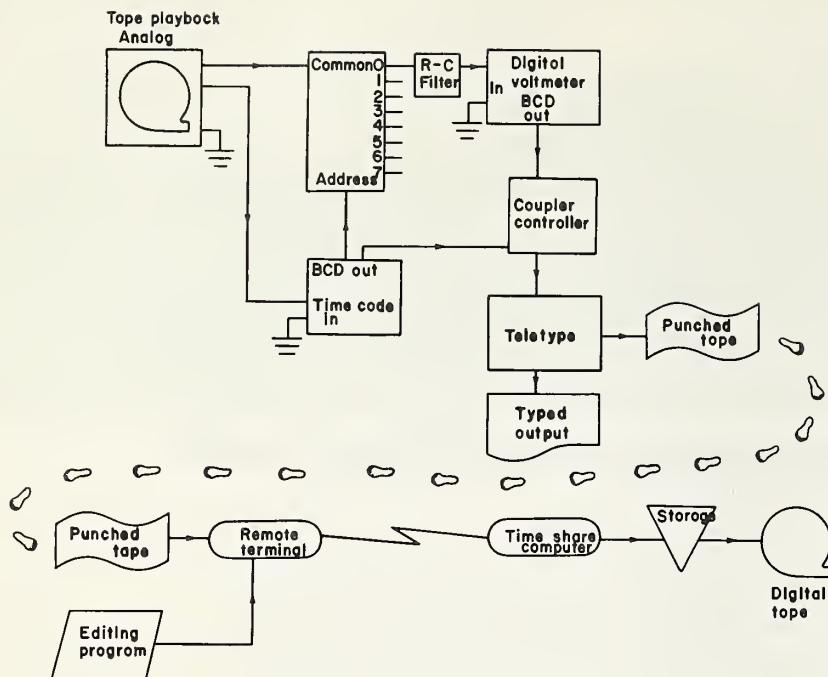
Figure 2.—Block diagram of the data reduction system. The time-cade track is translated by the clock which in turn cantrols the multiplexer ond the caupler-cantroller. The data flows through the multiplexer, is canditianed by the filter and digitized by the valtmeter. The caupler-contraller causes teletype to type and punch the time and the digitized dota. The punched tape is read into a remote terminal linked ta a time-sharing camputer. It is edited and dumped anto camputer compatible digital tape.

The major advantage ot this system is the automatic data processing, which greatly decreases the time necessary to reduce the data and eliminates clerical errors. The original analog recording is made with a minimum of data conditioning so that, as nearly as possible, the original signal can be recovered.

Equipment [2]

The tape recorder in this system is a Teledyne-Geotech model 19429, which records 14 tracks on 1-inch magnetic tape. Running at 0.06 inch per second, this recorder is capable of recording up to 17.5 days on 7,200 ft of 1-mil tape on a 14-inch reel. At this speed the FM frequency response is DC to 10 Hz. With direct recording, the frequency range is 0.2 to 125 Hz.

The time-code generator is a Datatron model 3150. It generates a modulated 100-Hz carrier, IRIG C time-code signal which codes the day (Julian), hour, minute, and second. The signal is recorded on one tape track using direct recording. The time-code generator also has a binary coded digital time output which is used to switch the multiplexers.

Since we record more sensors than the 13 free tape tracks, we use time-sharing multiplexers to record 8 sensors per track. The multiplexers are eight, single-pole, solid-state switches which are addressed by three lines of binary code (fig. 3). The multiplexers, which
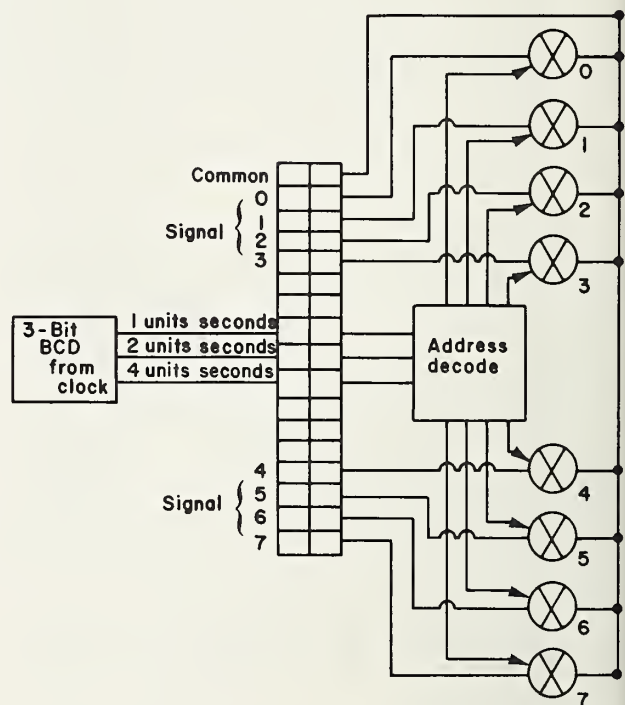
Figure 3.—Schematic diagram af a multiplexer. The BCD time code fram the clock is decaded by the address decoder, which clases each of the eight switches in turn. Far data acquisitian the eight data channels are switched sequentially anta the camman output. Far data reduction the recarded signal is fed inta the camman. Each signal is switched to the proper output at the proper time. The time cade track an the tape, translated by the clock, maintoins the necessary synchranizotian.

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are sold as small encapsulated modules, were mounted on printed circuit boards. These boards plug into a rack which supplies their required power and connects the inputs, outputs, and the address terminals to appropriate connectors on a front panel. The clock has binary coded digital (BCD) outputs for the tens and the units places of seconds. We wanted the multiplexers to switch once a second, so we used the binary outputs for units seconds to address the multiplexers. Since there are only 8 switches on the multiplexers, and 10 units seconds, 2 of the input signals are double-recorded on each cycle. The switching sequence is 0, 1, 2, 3, 4, 5, 6, 7, 0, 1 (fig. 4). The fact that channels 0 and 1 are double-recorded aids in identifying the different channels when playing the tape back.

The tape playback unit is a Honeywell model 7600. It can play back at speeds up to 120 inches per second, so that the data can be read 2,000 times faster than it is recorded. However, the time responses of the time-code translator and the multiplexers are such that they will not operate at speeds above 60 inches per second (time factor of 1,000). At 60 inches per second, a 7,200-foot reel of tape plays back in 24 minutes, roughly 1.5 minutes for each day of original recording time. The recovery of 120 days' data from one sensor takes about 4 hours, including tape changing, rewinding, and so forth.

The clock code track on the tape is decoded by a time-code translator (Datatron model 3000). This translator also has BCD time-code outputs which are used to control the same type of multiplexer as used for recording. With the clock switching the multiplexer in synchronization with the taped signal, the proper signal is switched to its proper output. A simple RC filter network provides a 5-minute (original recording time) running average of the signal, and holds the voltage level between switching. Because the input impedance of the voltmeter is very high ($>10^{10}\Omega$), it does not significantly drain the network when sampling the voltage.

The ones channel of the BCD units-hours output of the translator is also used to trigger the controller (Hewlett-Packard Coupler-Controller model 2570A). Every second hour (on the dropout of the signal) the controller causes the voltmeter to read and the teletype to type and punch on paper tape the day, hour, and voltage reading. The controller is also programed to print a numerical sensor identifier on each line. The format is shown in figure 5.

When all the data from a single sensor are recorded on paper tape, the tape is read into an XDS 940 time-sharing computer, using a remote terminal. It is stored there temporarily on disc files. This computer has a convenient editing program which is used to delete data which are

known to be in error, and to add calibration measurements performed during data recording. When the editing is completed the data are dumped onto digital magnetic tape which is compatible with a local computer. Computations on the data are then easily performed.
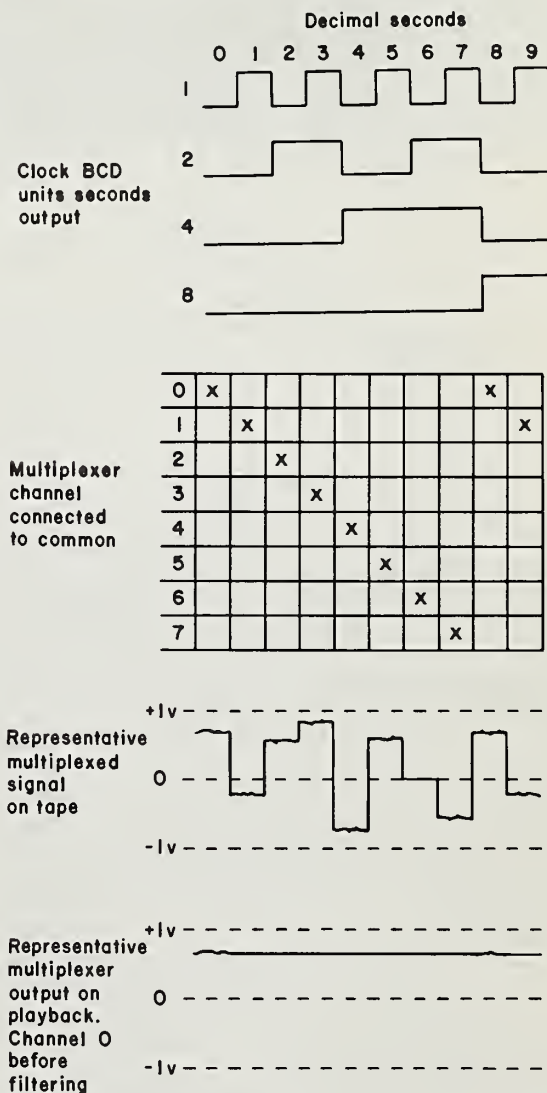

Figure 4.—Multiplexer timing diagram. Units decimal seconds are shown across the top with the logic levels for the BCD units seconds outputs just below. Next the multiplexer channel connected to the common at each second is shown. Since the 8 units seconds is not connected to the multiplexer, it receives the same BCD signal for 0 and 8 and for 1 and 9 decimal seconds thus double recording multiplexer channels 0 and 1 on each cycle. The next diagram is a representative single cycle of data as recorded on tape and fed into the multiplexer with the signal which appears at the 0 channel shown below. These various occurrences are synchronized by the clock system.

Sensor Code	Date	Time	Data	Calibration	
	065	190	.	−010320E−4	
				−053700E−5	418
1112	065	200	−074757E−5		
1112	065	220	−075774E−5		
1112	066	000	−077039E−5		
1112	066	020	−078349E−5		

Figure 5.—Final data format including inserted calibrations.

Conclusions

The system used is very flexible. It is capable of making long-term recordings of slowly varying voltage in the ranges ±0.1 to ±10 V. An accuracy of ±0.3 percent was achieved with the total system, and higher accuracy is possible with extra care. The recording system has run for 12 days without any attention, and the normal maintenance involved only tape changes and very minor adjustments of the recording amplifiers. Much of the reliability can be ascribed to the fact that the system was assembled from standard units of high reliability with a minimum of custom parts. Care of the recording system is well within the capability of most electronics technicians. The data editing has been done by a clerk-typist who was trained to operate the remote terminal.

The use of analog data recording insures that very nearly the original signal may be recovered. The signal can be conditioned as it is being played back. If the sensor signal is not multiplexed, it is recorded continuously. This reduces the number of possible data channels but allows the monitoring of transient phenomena which might be missed by a digital system with the same long-term recording capability. With the high-speed playback, the data can be scanned for transient phenomena very efficiently.

In its current configuration with four multiplexers, our system can record 41 data channels, 32 multiplexed and 9 not multiplexed. The initial cost of the system is about $40,000 and compares favorably with the cost of high-reliability strip-chart recorders for the same number of data channels. If the playback system can be used in other applications, its contribution to the total system cost is reduced proportionally. In such a case the initial acquisition cost for 20 data channels may be lower than a strip-chart system of the same capability. In addition, the automatic data processing saves at least a factor of 10 in the time required to reduce the data, and eliminates clerical errors in transferring and processing the data.